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ABSTRACT

Updating information on various developmental efforts in computer-based training, this report provides information on new developments that may have implications for Navy training. Although projects in the military services are emphasized, major developments in the civilian sector are also reviewed. The range of activities emphasizes the use of computers for teaching and includes a wide variety of computer aids to instruction. Information for this report was gathered from reports supported under a Navy contract and from a continuing survey of other developments in computer-based instruction. It is organized under five major topic headings: (1) military activities, (2) civilian activities, (3) systems developments, (4) current issues in instructional design, and (5) state-of-the-art and Navy training needs. An overview is provided for each of the major topic areas as well as for many subtopic areas. A supporting bibliography is also included. (Author/DGC)

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J. D. Fletcher

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This report updates information on various developmental efforts in computer-based training and provides information on new developments that may have implications for Navy training. Although projects in the military services are emphasized, major developments in the civilian sector are also reviewed. The range of activities considered emphasizes the use of computers for teaching, and includes a wide variety of computer aids to instruction.

Information for this report was gathered from reports supported under ADO 43-03X and from a continuing survey of other developments in computer-based instruction. The information is organized under five major topic areas: military activities, civilian activit es, systems developments, current issues in instructional design, and state-of-the-art and Navy training needs. An overview is provided for each of the major topic areas as well as for many subtopic areas.

FOREWORD

It is essential that the Department of the Navy be prepared to adopt advances in instructional technology to meet operational requirements and to achieve maximum benefits from these advances. The application of computers to instruction appears to be an area of instructional technology that holds particular importance and promise for improvements in training efficiency and effectiveness. Accordingly, it is the intention of the Navy Personnel Research and Development Center to review periodically the state-of-the-art of computer applications in instruction. The present report is intended to be current for the last quarter of calendar year 1974.

JAMES J. CLARKIN
Command Officer

SUMMARY

Problem

Required levels of personnel readiness are highly dependent on Navy education and training programs. It is therefore essential that the Navy be prepared to adopt advances in instructional technology that promise major improvements in training efficiency and effectiveness. Accordingly, research and development has been actively supported, particularly under Advanced Development Objective 43-03X, to test and evaluate new advances in instructional technology including an emphasis on computer aids in training. As a necessary part of this effort, the Navy Personnel Research and Development Center periodically reviews the state-of-the-art of computer applications in instruction. The present report is one of these reviews and is intended to be current for the last quarter of calendar year 1974.

Background

This report updates information on various developmental efforts in computer-based training and provides information on new developments that may have implications for Navy training. Although projects in the military services are emphasized, major developments in the civilian sector are also reviewed. The range of activities considered emphasizes the use of computers for teaching, and includes a wide variety of computer aids to instruction.

Approach

Information for this report was gathered from reports supported under ADO 43-03X and from a continuing survey of other developments in computer-based instruction. The information is organized under five major topic areas: military activities, civilian activities, systems developments, current issues in instructional design, and state-of-the-art and Navy training needs. An overview is provided for each of the major topic areas as well as for many subtopic areas. These overviews attempt to consolidate and characterize substantial amounts of specific information.

Findings and Conclusions

The use of computer-based training in the military has developed a momentum that makes its continued expansion very likely. However, systematic research into the economic, technological, and pedagogical impact of computer-based training has lagged behind its operational implementation. There is a strong, but not exclusive, emphasis in the Air Force on plasma panel technology. The major Air Force research effort centers on the Advanced Instructional System being developed by the Human Resources Laboratory at Lowry Air Force Base. In the Army, there is an emphasis on immediately practical and specific aspects of training and on the use of self-sufficient military instructors to author

computer-based training. The major research effort in the Army centers on the development of a Computerized Training System by project ABACUS. In addition to this project, there is a wide and varied use of computers to support training in the Army. The Navy has a substantial commitment to computer-based training, but it has not focused on a single large project as have the Air Force and the Army. The Navy's emphasis is on research and development of a variety of techniques.

The use of computer-based training in the civilian sector continues to expand despite diminishing federal support. As in the military, many civilian applications have been rushed into operational environments without systematic empirical investigations of the assumptions underlying the implementations. However, significant successes have been achieved using computers in instruction. Conclusions common to two major reviews of civilian activities are: (1) computer-based training is at least as effective as traditional training, (2) more experience is needed with improved and more imaginative applications of computer-based training, (3) the success of computer-based training appears to be increasingly less dependent on hardware costs and opportunities should exist for substituting capital for labor as the costs for technology relative to labor continue to decline, and (4) there is a need for long-term evaluations of sustained computer-based training projects.

Two systems developments that directly affect CAI are the emergence of new computer terminals and new communication techniques. Although improvements in main-frame hardware, memory, and peripheral storage devices may provide major breakthroughs with immediate implications for computer-based training, the gradual development of terminals and communication techniques continues to hold current relevancy for reductions in costs and increases in efficiency.

Issues in computer-based training are complicated by competing interpretations of what this type of training should do. The following issues were identified and discussed on the basis of the substantial attention they are currently receiving: (1) computer-managed instruction, (2) use of models, (3) student control, (4) authoring and author languages, and (5) cost of materials preparation.

Special requirements are placed on the characteristics of training systems designed to meet Navy needs. These systems must be (1) capable of decreasing training costs, (2) distributed, (3) portable, and (4) relatively instructor free. If computer-based training systems can be designed to meet these requirements, they should provide a modularity of instruction that is uniquely beneficial to the Navy. The techniques of optimization, student control, computer-generated instruction, and simulation should yield improved training at a cost that is not only lower than the production cost of current computer-based training materials, but lower than many other forms of instructional materials production as well. Compact, powerful, rugged, and inexpensive computer systems are rapidly becoming a reality. These new computers can have a major impact on Navy training, as research and development provide new information that will adapt them to training use with increased efficiency. On-line testing, test scoring, diagnostic test analysis, record keeping, optimal allocation of training resources, and personnel guidance are all functions that could be automated to some extent in support of instruction delivery. Finally, computer-based training offers a precision in evaluation and a facility in modification that is unique among training media. The use of computer-based training promises major improvements in the economy and efficiency of Navy training.

CONTENTS

INTRODUCTION

Purpose and Organization

The purpose of this report is to identify (1) current computer-aided instruction (CAI) activities in the military, (2) major CAI activities in the civilian sector, and (3) current issues in CAI. An attempt was made to provide comprehensive coverage of military CAI activities. Civilian CAI activities were selected for their prominence, currency, and relevance to the Navy. A broad range of CAI activities was considered; it was not limited to the direct use of computers for teaching but included a variety of computer aids to instruction. Distinctions among instruction, training, and education, although quite real, were not considered necessary for this report and these three terms are used interchangeably.

Sources

Several recent surveys were helpful in the preparation of this report. Hoye and Wang (1973) have edited the fourth edition of the Index to Computer-based Learning. This source claims to be "the most complete and functional listing of its kind anywhere" (p. vii). With 1766 entries from several countries covering military, industrial, and academic applications, this claim is not unreasonable. Two groups of scholars, one from Sweden and one from Scotland, have prepared evaluative overviews of CAI in the United States, based on extensive tours of facilities in this country. Andersson (1973) summarized, with evaluations and recommendations, the use of computers in schools for the Swedish National Board of Education, and Docherty, Bain, and Watt (1973) prepared a similar report for the Corporation of Glasgow. Jamison, Suppes, and Wells (1974) surveyed research on the effectiveness of alternative instructional media. This survey included instructional radio, instructional television, programmed instruction, and computer-assisted instruction. Vinsonhaler and Moon (1973) surveyed information systems applications in education under the categories of computer-supported instruction, computer-aided testing, computer-managed instruction, and computer-administered instruction. Hickey (1974) surveyed leaders in CAI to determine guidelines for computer-assisted instruction. Rich and Van Pelt (1974) documented an invaluable survey of CAI activities in the Army. Finally, the Navy Personnel Research and Development Center's previous special report on computer applications in education and training (Computer Applications, 1973) was an important resource for this report.

MILITARY ACTIVITIES

The use of CAI in the military has developed a momentum that makes its continued expansion very likely. However, systematic research into the economic, technological, and pedagogical impact of CAI has lagged behind the implementation of operational CAI. Feedback from operational implementation provides both incentive and focus for follow-on research. The rush to make CAI operational has produced dramatic payoffs in the civilian sector, and it seems reasonable to expect similar payoffs for the military. However, the need for systematic empirical support of CAI practice remains, and its importance and utility can only increase as CAI receives increasing support.

Caution is necessary in interpreting labels and catch phrases used to identify CAI activities. These labels are so general that two installations claiming exactly the same CAI activities are likely to be practicing quite different forms of CAI.

Air Force

There is a strong, but not exclusive, emphasis in the Air Force on plasma panel technology in CAI. At Chanute and Sheppard Air Force Bases, this emphasis involves direct use of the PLATO (Programm [illegible] for Automated Teaching Operation) system based at the Unive[illegible] Illinois. At Lowry Air Force Base, the emphasis involves the design and implementation of a new computer system to support plasma panel terminals. However, despite the use of plasma panel terminals by all three locations, the philosophy and impact of each installation's CAI activity are distinct.

Lowry Air Force Base - Advanced Instructional System (AIS).

AIS is an advanced development of the Air Force Human Resources Laboratory, Technical Training Division, and it represents the major effort by the Air Force in CAI. AIS was discussed by NAVPERSR&DCEN (Computer Applications, 1973), Rockway and Yasutake (1974), and a training bulletin (Technical Training Division Bulletin, 1974). The recent references indicate that AIS will support individualized instruction in four, rather than three, courses: Inventory Management, Material Facilities, Weapons Mechanic, Precision Measuring Equipment. Milestones for AIS and these four courses are:

. AIS computer installation	Feb 74
. Course materials for Inventory Management and Material Facilities	Nov 74
. Initial CMI capability	Nov 74
. Initial CAI capability	Feb 75
. Course Materials for Weapons Mechanic	Apr 75
. Course Materials for Precision Measuring Equipment	Feb 76

Seven major subsystems for AIS have been identified:

- Instructional materials
- Instructional strategies
- Media
- Computer software
- Computer hardware
- Personnel and training
- Related subsystems

The contract for implementation of these subsystems was awarded to McDonnell-Douglas Corporation, for the period May 1973 through May 1977, for an estimated $9.9 million.

The emphasis in AIS is on full-scale instructional systems design to increase the cost-effectiveness of instruction using a variety of media. The project will attempt an optimal synthesis of current technology into an inte ated system for administering and managing individualized in-struc a large scale. AIS represents a major effort to develop a com directed multimedia system for a large centralized training facility.

Rockway and Yasutake emphasize that:

> "... although much of the component technology to develop the AIS is largely state-of-the-art, the AIS itself is unique in a number of respects. First, it will be the first attempt to integrate all of the technology required for the cost-effective implementation of individualized instruction on a large scale. Second, unlike most current systems which involve a commitment to a single or limited number of approaches such as programmed instruction ... the AIS will provide a capability for the utilization of several available methods and media. Third, the AIS contains within it the capacity for incorporating new instructional and management innovations as they become available. Fourth, inherent within the AIS is a capability for continuously evaluating and upgrading its own cost-effectiveness. And, finally, the AIS is being designed as a total system to perform all of the instructional system design, administration, and management functions required to conduct a large-scale training enterprise." (p. 238)

Chanute Air Force Base - PLATO IV.

As part of the experimental evaluation of PLATO IV sponsored by the Advanced Research Projects Agency (ARPA) (Computer Applications, 1973), the Technical Training Center at Chanute Air Force Base is developing a 12-week CAI course in special vehicle maintenance. This project can be characterized as adjunctive computer-based instruction for a centralized training facility. Students are given on-line CAI on 22 PLATO IV terminals interspersed with off-line, hands-on experience with vehicles. Communications between the central computer facility at the University of Illinois, Urbana-Champaign, and 18 of the PLATO terminals are currently supported by microwave rather than by dedicated telephone lines. Twenty-nine learning objectives are presented on the PLATO system while the remainder of the course is relegated to hands-on instruction. The Air Force Human Resources Laboratory will evaluate five aspects of the system: cost, instructional effectiveness, instructional impact on management, instructional development, and human factors.

Sheppard Air Force Base - PLATO IV.

The Air Force School of Health Care Services plans to use about 20 PLATO IV terminals to present clinical simulations to trainees for physician's assistant. These simulations will supplement the instruction provided by the school to about 192 students, half from the Air Force and half from the Navy. The simulations will, in turn, be supplemented by direct computerized instruction in the basic sciences, so that students may begin to use the PLATO simulation during the first few months of their training. The project is an example of adjunctive computer-based instruction for a centralized training facility. It is expected to be fully operational with all course development completed by October 1976.

Computer Directed Training System (CDTS).

CDTS consists of CAI designed to provide instruction in the operational characteristics of the host computer system, and was described in more detail by NAVPERSR&DCEN (Computer Applications, 1973). Current plans are to add courses as required by additions to or modifications in the host computer system. The system is currently operating at about 130 Air Force bases, and it is an example of terminal-based training for dispersed facilities.

Army

There is an emphasis in the Army on immediately practical and specific aspects of training, rather than on theoretic and general aspects. Although there is substantial use of teams to author instructional material, the use of self-sufficient military instructors is emphasized in authoring material for CAI. This emphasis is apparent in the design of the Computerized Training System (CTS), which is the major CAI project supported by the Army. Interest in computer support of training is as strong in the Army as it is elsewhere. Rich and Van Pelt (1974) indicated that 15 of the 34 Army training activities surveyed used computers in support of training. Nine of these activities are discussed here.

Signal Center and School, Fort Monmoth - Computerized Training System (CTS).

CTS is sponsored by Project ABACUS which was established at the Signal School in 1972 to develop and evaluate a 128-terminal system for eventual use in Army training activities. A Task Group Report (1972) supported this activity by calling for the development and evaluation of a large-scale CAI system as a justifiable evolutionary step to capitalize on the growing potential of CAI. Project ABACUS was discussed earlier by NAVPERSR&DCEN (Computer Applications, 1973). CTS can be characterized as terminal-based training for a centralized facility.

A contractor has been selected for CTS and work is progressing on schedule. CTS has been configured as a cluster of small (PDP-11/35) computers. One computer will serve as a systems controller for the basic timesharing functions, one will serve as a data-base controller, and several will be added as display controllers, one for each cluster of 32 student terminals. Although the systems controller can support a variety of terminals and alternate applications, the system is designed primarily to support the CTS authoring language, CLASS I, and student terminals consisting of video visual display units with keyboards. CLASS I is intended to be a simple CAI authoring language that can be used by military instructors after 3 to 4 weeks of training.

The system supports five modes of operation: student mode, instructional programmer mode, instructor mode, systems programmer mode, and administration mode. The following discriptions are taken from summary documentation on CTS (Booklet B: Concept Plan, 1973):

> "Student mode. The student mode of operation is the most important of the five modes. The student will be taking a course which is approximately 300 hours in length, and upon completion, should be technically competent in the subject matter. He will be on or monitored by the system five days a week, eight periods a day, for as long as it takes him to complete the course. Being completely self-paced, this could be as little as three or four weeks, or as long as fifteen or so weeks. This will depend upon the individual student's capability. The student can skip material, go over the same material more than once, or be given individual instruction by the CTS Classroom Instructor, based on his aptitude and performance." (p. 4)
>
> "To the student, it will appear as if he is the only person utilizing the system. All key echoing and system responses to queries will be just about instantaneous. This will be the case whether there is one or 128 students on the system at any one time. Further, any CAI terminal will be capable of providing instruction from any one of the three proposed courses, and presentations from these courses will be going on at the same time. The student will be completely managed through the course by the CTS." (p. 4-5)
>
> "Instructional programmer mode. The CTS in the Instructional Programmer (IP) mode will permit course material to be entered directly into the system using a terminal. Bulk entry of course material will be done by Instructional Program Entry Specialists (IPES) inputting at near average typing rate, 40 - 50 words per minute. The IP will be able to edit and revise the course material on line at a terminal. Both the IP and the IPES will share the same set of commands and special function keys."

"All lesson material in the system may be reviewed by any IP using a legitimate security code ... During the lesson creation period, access to lesson material for editing will be made available only upon the validation of a security code. Once the lesson material is in final, approved form, editing will be permitted by those specifically authorized. A security code that will be different from the IP's code will be used to secure the lesson material." (p. 7)

"Instructor mode. The instructor in the CTS concept is the classroom manager. He is present to provide individual aid to students as he is directed by the system or his own knowledge of student troubles. His terminal will be basically the same as a student's with the addition of a hard-copy output device of some type." (p. 8)

"The system to the instructor is, therefore, his assistant in managing the class. The system provides the instructor with information on how each student is progressing and any student problems. The hard-copy device then becomes an important part of the instructor terminal, for it will provide him with a log of who requires assistance while he was helping someone else, and is a means whereby he can receive permanent hard-copy reports on students. The terminal will provide him with answers to queries, and through the use of the keyboard and proper commands, the instructor will be able to communicate one way with any given student." (p. 9)

"Systems programming mode. The system programmers using their security code can operate from any one of the configured terminals and may use more than one at a time. Through this terminal the system programmer will be able to retrieve or alter any data stored within the system." (p. 9)

"Administrative mode. The administrative mode of the CTS covers all administrative requirements in which student records are involved. Any one of the configured terminals can operate in this mode using the proper security code. There may be more than one administrative terminal operating at a time. Constructed courses may be used to massage summative real-time data, register students or perform other administrative type tasks." (p. 9-10)

Delivery of CTS was scheduled in three steps: (1) a display controller and some system-controller peripherals were delivered to Fort Monmouth in April 1974, (2) a 32-terminal display-controller subsystem and some of the CLASS I software were delivered to Fort Gordon in July 1974, and all remaining equipment and softwere were delivered to Fort Gordon in January 1975. The Fort Monmouth CTS equipment will be moved to Fort Gordon and integrated into the CTS system there in early 1975.

In addition to Booklet B cited in the previous paragraphs, conceptual documentation of CTS includes: (1) Booklet A: Record Formats (1973), (2) Document A: CLASS I Language (1973), and (3) Document C: Estimated System Use Factors (1973).

Command and General Staff College, Fort Leavenworth.

Plans for the Command and General Staff College call for each student officer to become sufficiently familiar with computer terminals and with the BASIC programming language to use the computer as a tool in course work and in research. In this application, the computer is an integral aspect of the curriculum, but it is primarily intended as a tool for students, rather than for instructors.

Engineer School, Fort Belvoir.

The Engineer School uses CAI to provide instruction about computers. ASR Model 33 teletypewriters are used for drill and practice in two courses: Engineering Officer Advanced, and Engineering Non-Commissioned Officer Advanced.

Infantry School, Fort Benning.

The infantry school is using computer-based tutorial simulations of a variety of tactical situations to provide decision-making training which is otherwise available only through participation in combat operations. This training centers on two simulated combat options: (1) a ground command post environment for conduct of tactical ground operations, and (2) a command control helicopter environment for conducting airmobile tactical operations.

Ordinance Center and School, Aberdeen Proving Ground.

CAI activity at the Ordinance Center and School primarily concerns use and evaluation of 14 PLATO IV terminals as part of the ARPA-sponsored evaluation of PLATO IV discussed by NAVPERSR&DCEN (Computer Applications, 1973). The emphasis of this project is on training machinists with a variety of proficiencies. The training techniques resemble those used at Chanute Air Force Base in that direct PLATO-based computerized instruction is interspersed with off-line, hands-on training. Instruction is managed by instructors who are responsible for groups of 8 to 12 students.

Quartermaster School, Fort Lee.

The Quartermaster School supports a variety of simulations designed to provide stock control and accounting training to enlisted students. The following seven simulations are currently being used:

- COSINES - Computer Supported Instruction for Enlisted Supply
- SIMTASS - Simulation, Theatre Army Supply System
- COSTORE - Computer Support for Storage, Enlisted Supply
- SIMWIM - Simulation, Wholesale Inventory Management
- SIMSON - Simulation, Storage Operations Management
- CRASE - Cornell Restaurant Administration Simulation Exercise
- SIMPLEX - Simulation, Petroleum Laboratory Exercise

The following four simulations are currently being developed:

- SIMSAX - Simulation, Spectrometric Analysis Exercise
- SIMFIN - Simulation, Financial Management
- SIMCOM - Simulation, Commissary Operations Management
- SIMPRA - Simulation, Pipeline Route Analysis

Additionally, six small NCR 500 computers provide support-unit training.

Logistics Management Center, Fort Lee.

The Logistics Management Center made the following statement, which effectively speaks for many training organizations that have turned to computer-based simulations:

> "One of the primary objectives of our Center is to train our students in effective supply management. In support of this objective, the question was asked, 'What really makes one man a more effective supply manager than another?' It was found that in addition to having the necessary basic attributes of intelligence, flexibility, adeptness, etc., that what made one man a better manager than another was generally years of experience. The question we were faced with was how could we, in the few short weeks that our students were with us, give them years of experience. The answer we found, was to use computer simulations to compress time: thereby giving our students what we call 'accelerated experience.'" (Rich and Van Pelt, p. M-20-21)

The Logistics Management Center is using computer-based simulation to extend the case method approach to instruction in which solutions devised for problems that actually occurred are critiqued by students. There are two aspect to the extension. First, in studying a case, the student can be relatively objective, but in a simulation he is subjectively involved. Second, because of the time compression possible under computer-based simulation, the student is forced to live with his decision. The consequences of his decisions may never be realized in a case-study approach because of incomplete data.

Security Agency Training Center and School, Fort Devens.

The principal CAI activity at the Security Agency Training Center involves the Morse Code Trainer which is an on-line, real-time CAI system providing about 260 hours of instruction for each student. The operational equipment is directly connected to a dedicated computer, and presenting stimuli, processing students responses and performance data, and responding to instructors inputs are all handled in real time. The Security Agency School has submitted a proposal to interface computer applications with all instruction given at the school.

Academy of Health Science, Fort Sam Houston.

The Academy of Health Sciences is presenting CAI on an IBM 1440 Coursewriter I system with IBM 1050 student stations. This is probably the last system of this type in use, and it is scheduled for removal in FY75.

Navy

Although the Navy has a substantial commitment to CAI, it has not focused on a single project such as AIS in the Air Force or CTS in the Army. The Navy's emphasis remains on research and development of a variety of CAI techniques. Specific applications in training are being implemented, but the variety of these applications indicates the eclectic approach currently adapted by the Navy.

NAVPERSR&DCEN - PLATO IV.

Twelve terminals on the PLATO IV network are currently being used by NAVPERSR&DCEN as part of the ARPA-sponsored evaluation of PLATO IV discussed earlier (Computer Applications, 1973). Eight terminals are located at the Naval Training Center, San Diego, California, and four are located at Naval Air Station, North Island. The following five training courses are being investigated:

1. Multimeter simulation and training. This course presents simulation of front-panel topography and functional organization of the PSM-4 meter. It provides four hours of instruction on using the meter as an ohmmeter and ammeter in Basic Electricity/Electronics School. Evaluation with 30 students was completed during the second quarter of FY75.

2. Recipe conversion. Instruction on mathmatical solutions and the use of job aids for recipe conversions taught in the Commissary/Steward "A" School are presented. The course provides two to three hours of remedial training for failing students. Evaluation was completed during the second quarter of FY75.

3. Low-cost trainer simulation. This work investigates the technical, operational, and economic feasibility of PLATO IV as a low cost simulation trainer. The S-3A INCOS copilot panel keyboard, ball tracker, cursor, and readout matrix display are simulated, using PLATO terminals in place of the more expensive and less available Position Trainers. The course currently uses 10 S-3A copilot trainees and requires one to three hours per man.

4. <u>Oscilloscope training through simulation</u>. Approximately four hours of basic oscilloscope training is provided through PLATO IV simulation of important controls and functions. Evaluation of the simulation used three classes drawn from the sonar A-1 phase of the ASW School in the second quarter of FY75. Each class consisted of approximately 20 students.

5. <u>Computer-based guidance of oscilloscope training</u>. Use of PLATO for computerized guidance of hands-on training is being investigated. Several techniques for oscilloscope training are being evaluated using forty subjects from Basic Electronics School each of whom receives four hours of PLATO training in place of regular training.

As indicated by a NAVPERSR&DCEN training development plan (Technical Development Plan, 1974), significant problems have been encountered in the PLATO IV evaluation. These problems were directly related to peripheral components of the PLATO terminal and to the TUTOR language.

It was impractical to use the slide selector, touch panel, and/or audio device in many of the research studies. Although slide selectors were delivered with each terminal, no documentation was provided to guide in the preparation of art work or photographs for microfiche. In several instances the use of microfiche visuals was decreased or discontinued after numerous failures to achieve acceptable quality in visual acuity and/or color tone. Touch panels and audio components were not provided with the originally installed terminals, and their delivery dates were not available for planning milestones. With less than six months remaining of the three year project, only three of the 12 terminals had touch panels installed. The single audio device designated for the site was received during the last 12 months of the project, and there has been little documentation provided on methods and techniques for its use.

Finally, the TUTOR language was not stabilized, standardized, or adequately documented during the first half of the project. Most documentation was maintained on-line in PLATO lessons and could only be studied at a terminal. The amount of time spent learning new codes and changing old programming for compatibility with new codes greatly reduced the efficiency of programming materials.

Despite these problems, use of the plasma panel terminals, available touch panels, and limited slide-selector visuals is expected to provide an adequate evaluation of the PLATO IV technological capabilities.

<u>Shipboard Computer Training Applications</u>.

The use of computers aboard ship for instruction and training administration purposes has been discussed in earlier reports (Flint and Graham, 1971; Computer Applications, 1973). This effort is currently being pursued by NAVPERSR&DCEN. The project addresses the feasibility of using minicomputer systems aboard combatant ships for instructional and training administration purposes. The project can be characterized as computer-directed multimedia training for dispersed facilities. For the instructional knowledge and skill applications, General Damage Control has been selected for prototype development and test and evaluation.

Instruction will be in the computer-integrated instruction (CII) mode (consisting of off-line, self-paced instruction) and on-line testing, both under computer management. The CII application is expected to consist of about 25 hours of off-line instruction and five hours of on-line testing. The off-line media include programmed instruction, audio, sound-on-slide, and self-study guides. The five hours of testing will be done on-line at CRTs or off-line as physical demonstrations of proficiency. Off-line test results will be entered into the computer system.

A Shipboard Training Administration System (STAS) application is also being developed. One purpose of training administration is to assure that shipboard training programs are managed effectively by coordinating training schedules, training resources, and personnel resources. Other purposes are the career advancement of individuals and the operational readiness of individuals and teams. Currently these functions require substantial amounts of data and information to be processed manually. Significant gains in efficiency will be achieved if, under STAS, this information can be processed by computer.

The prototype CII and STAS applications are being developed ashore with contractual support. They will be installed aboard the demonstration ship, USS DAHLGREN (DLG-12), in January 1975. Shipboard test and evaluation will be accomplished jointly by NAVPERSR&DCEN and COMCRUDESLANT, with OP-91 (Information Systems Division) support. The shipboard mini-computer system has been installed. Qualified ADP personnel have been assigned to the DAHLGREN to expedite this project and related projects. COMCRUDESLANT will designate a sister ship to serve as a control for empirical comparison. Aboard the control ship, General Damage Control training and training administration will be accomplished in the conventional manner without computer assistance.

North Island Naval Air Station.

Starting early in 1975, approximately 15-20% of the training given to S-3A air crews at North Island Naval Air Station (NAS-NI) will be presented by a TICCIT (Time-Shared Interactive Computer-Controlled Information Television) system. The project is intended to provide terminal-based training for a centralized training facility. Negotiations leading to implementation started early in 1973 with a survey by NAS-NI personnel of available CAI systems. TICCIT was selected on the basis of cost, system size, and the availability of contractor personnel to assist in the development of both CAI and non-CAI training materials. Training objectives, learning hierarchies, and lesson specifications were completed in 1973, followed by the development of individual training segments. Air crew training started in July 1974, substituting workbook sequences for training areas identified as best-suited to CAI.

The TICCIT system was installed at NAS-NI in January 1975, and will be operational with 32 student terminals by May. Eventually, it is anticipated that 30% or more of the total training for the S-3A crews will be presented in the CAI mode.

Following a job task analysis by NAVPERSR&DCEN, NAS-NI personnel were assisted by the contractor in developing learning hierarchies, lesson specifications, and lesson content. NAS-NI is currently processing the CAI materials in the TICCIT format (generalities, instances, practice, helps) for final review and packaging, with encoding of the lessons to be accomplished by the contractor following installation and acceptance testing in February 1975.

Assuming that behavioral objectives, learning hierarchies, and generalities pertaining to the objectives are already prepared, and that some current lesson materials may be converted to TICCIT, it is estimated that the cost of developing the courseware will be about $1000 per student-contact hour. Hardware costs, including purchase price and installation charges from the contractor but excluding alterations to the buildings, were roughly $12,500 per terminal for the NAS-NI system. Additional terminals, up to 128, should cost less than $1000 per terminal. With the cost of maintenance services estimated at $15,000 per year, and assuming a 10-year operational period during which the terminal use is roughly 12,800 hours per year, the cost of the system may be estimated at $6.20 per student-contact hour. This contrasts with costs reported by the Association for the Development of Computer-Based Instructional Systems (ADCIS) of up to $1000 per student-contact hour for existing services. Current plans for the S-3A TICCIT system are to increase the number of segments prepared for CAI, so that the cost may be even less.

<u>NAVPERSR&DCEN/ARPA - Advanced Computer Based Training Research.</u>

The purpose of this program, which is sponsored jointly by NAVPERS-R&DCEN and ARPA is to examine techniques for implementing computer-based instruction in Navy training. The four principal research areas are discussed below:

1. <u>Computer-assisted instruction study - management system (CAISMS).</u> A contract is continuing with the University of Illinois to design, develop, and evaluate a set of procedures for maintaining attentive study of instructional materials. The major difference between CAISMS and other CAI projects is that materials already prepared are used, and the student spends only a fraction of time on-line under direct computer control (Allessi et al, 1974; Anderson et al, 1974). An empirical comparison of CAISMS with standard instruction in economics showed significant gains in achievement for students using CAISMS. Substantial progress has been made in developing a new version, CAISMS II, which will incorporate a complete CMI system.

2. CAMELOT/GRAIL. Software and hardware support for NAVPERSR&DCEN CAI simulation research is being provided under contract with the San Diego State University Foundation. The system includes a general purpose CAI system (CAMELOT), an associated author language (GRAIL), and a general purpose data recording and retrieval capability. The system supports Tektronix graphics terminals with random access slide projectors and Votrax voice synthesizers. This effort is unique in that it supports a macro capability in a higher-order, graphics-oriented language (GRAIL), and a provision for visual graphics in which a graphic "universe" is established that can be viewed through the CRT "window" at specifiable locations and levels of detail.

3. Automatic question-generation and response evaluation. The purpose of this project is to explore and develop techniques for automatically generating questions from textbook material. Rather than depend on pre-stored questions and anticipated answers, these techniques should result in a system that generates its own questions, evaluates student responses, and devises appropriate, individualized branching sequences from a data base consisting solely of pre-stored, expository text. The current emphasis of this project is on generating questions from text sentences. This work is proceeding through four stages: (1) existing deep-structure English parsers (e.g., Winograd, 1972; and Woods, Kaplan, and Nash-Webber, 1972) will be implemented, (2) questions generated by human subjects from text sentences will be examined, and an attempt will be made to identify rules for generating these questions, (3) computer programs that implement these rules will be written and, (4) programs to automatically evaluate student responses to these automatically generated questions will be written and empirically tested. This project is scheduled for completion in June 1975.

4. Computer based assessment of job oriented training. A realistic simulation of troubleshooting a radio receiver will be developed, using a standard CAI terminal and a computer-controlled random access image projector. In addition to the logical aspects of troubleshooting, the simulation will reflect task requirements of actual troubleshooting, including interpretation of oscillograms and use of technical manuals. Automated performance measures will be developed and evaluated. The effectiveness of the simulation and the troubleshooting measures will be determined by comparing performance on simulated and actual equipment, by comparing performance of personnel with varying skill levels, and by measuring performance over a variety of troubleshooting problems.

Lesson Translator (L-TRAN).

The L-TRAN project focuses on a terminal-based system for dispersed training. As described by NAVPERSR&DCEN (Computer Applications, 1973), L-TRAN is a software program that accepts lesson material, translates it into computer operable instructions, and displays it on Navy Tactical Data Systems UYA-4 shipboard consoles. There have been no major conceptual nor methodological developments in this effort since the 1973 description by NAVPERSR&DCEN. However, there have been appreciable improvements and extensions with respect to lessonware content in both the Atlantic and Pacific Fleets. Although no systematic evaluation has been completed, ships continue to comment favorably on the value of the program.

Marine Corps, Twenty-Nine Palms.

At the Marine Corps Communications and Electronics School, Twenty-Nine Palms, California, CAI is being used for troubleshooting and other portions of the Basic Electronics and Fundamentals course. This COPI (Computer Oriented Programmed Instruction) system uses Uniscope 300 terminals con-nected by a communication concentrator to a remote Univac 1108 computer at Corona Naval Weapons Facility.

A continuing contractual Training Improvement Program for the Marine Air Command Control System (MACCS) maintenance and operator courses includes plans for expanded use of COPI into other courses. It is estimated that 119 instructional hours (about one percent of the total course time) will be devoted to computer based instruction in the revised MACCS training courses. Additional terminals and associated facilities will be required to support this expansion.

Naval Training Equipment Center - Individualized Adaptive Training System.

The aim of this research is to develop a validated model for individualized adaptive training of complex tasks such as aircraft maneuvering. Training of such complex skills has been hampered by a lack of automated performance measures on which to base adaptive remediation and by a reliance on simple linear bypassing as the primary adaptive mechanism. The project may aid in solving both these problems. The model will incorporate recent advances in computerized performance measurement, adaptive variable control, and adaptive logics. The validated model should be available about 1976-77.

Five preliminary studies will feed into the development and validation of the final refined model. Canyon Research Group, Inc., is contracted to develop an adaptive training model that incorporates recent advances in performance measures for control movement and use of continuous and discrete performance measures appropriate to the stage of training. In another contract, Bolt, Beranek, and Newman will study interactions of superior instructors with students as a basis for developing a training model which dynamically adapts instruction to the trainee's changing abilities and difficulties. Two in-house studies will attempt to solve some performance measurement problems involving the interaction of the Performance Measurement Interval (PMI) with the period of the phugoid (long-period changes in pitch of aircraft). Another in-house study will determine the best training progression from one- to two-dimensional tasks.

NAVPERSR&DCEN - Computer-Managed Instruction (CMI).

This project supports development of an integrated system for job-specific training and assignment. Initial aspects of this project were conducted in two phases by the Memphis branch of NAVPERSR&DCEN. The first phase concentrated on a computer managed system directed primarily toward support of the instructional process rather than toward support of administrative functions. The resulting system assigns instructional materials and tests, scores the tests, determines those topics on which the trainee needs remediation, tracks the trainee's position within the course, evaluates his rate of progress, predicts his date of graduation, assigns grades, and provides management with roster printouts.

Evaluation of the management system developed under the first phase was accomplished in the Aviation Familiarization/Aviation Mechanics Fundamentals sequence, two preparatory courses for most of the aviation maintenance rating Class "A" courses at the Naval Air Technical Training Center (NATTC), Memphis. Results indicated that graduates of the computer-managed system courses were more proficient than those of the conventional instruction system and required approximately half the training time.

The second phase tested the feasibility of such a system for providing a complete technical training sequence tailored to the specific requirements of particular jobs in the Fleet.

The modified computer management system developed in the second phase was evaluated on three organizational-level billets in an A-7E squadron: (1) Plane Captain, (2) Structures/Hydraulics Maintenance Technician, and (3) TF41-A-2 Powerplant Maintenance Technician. The normal training sequences for these three billets includes "P" Schools, "A" Schools, NAMTRADET (Naval Air Maintenance Training Detachment) courses, and/or FRAMP (Fleet Replacement Aviation Maintenance Training Program) courses. The evaluation demonstrated that the CMI trainees required considerably less training time (as much as 40%) than trainees given the conventional instruction (Technical Development Plan, 1974). A follow-up study of these trainees is underway. This project was documented by Carson et al. (1974). Although Carson et al. discuss direct computerized instruction and CMI, no systematic, empirical comparison of these two approaches was attempted under this project.

U. S. Naval Academy - Annapolis.

Hoye and Wang (1973) list 10 terminal-based CAI courses for the Naval Academy, representing three directions of development: (1) CAI based on teletypewriters, (2) CAI based on the IBM 1500 system, and (3) an Office of Education project that funded investigations of multimedia-course presentations. These efforts were halted in 1972-73 in favor of a different approach to computer support of instruction. This approach can be roughly characterized as that advanced by Luehrmann (1972) who suggests that for a technological society, computing is a form of literacy perhaps as basic to the society as reading and writing. Computing then becomes a fundamental resource for all endeavors of the society, including instruction. In practice, this approach implies that instructors and students both should learn to use a computer as a basic tool in instruction. This approach is being followed by the Academy. Use of the computer as a tool for students receives as much emphasis as its use as a tool for instructors.

The Academy has purchased a Honeywell-General Electric 635 Dartmouth computer system which is used in about two-thirds of the courses offered. Applications include a large, continually updated relational storage system for (1) transactions in international politics used by the Political Science Department, (2) simulation of the Eastern Coastline for training in navigation, and (3) use of graphics in engineering and weapons systems training.

Academy personnel emphasize that their use of computers in instruction receives its current impetus and support from instructors and not from higher-level, a priori commitments, to CAI. Roughly, the CAI efforts at the Academy can be characterized as adjunctive computer based instruction for a centralized facility.

Office of Naval Research (ONR).

ONR is continuing to support investigations of cognitive processes and their application to training Navy and Marine Corps personnel. The goal of this research is to improve student performance through better understanding of the underlying learning processes. Key issues include the definition and measurement of learning criteria and the effects of instructional sequencing and different methods of structuring information on learning and remembering.

The following projects are being supported by ONR:

1. STATNET and FLOW - Donald Norman, University of California, San Diego.

2. SCHOLAR - Allan Collins, Bolt, Beranek, and Newman.

3. Improving Navy training through CAI - Richard Atkinson, Stanford University.

4. Computer-based training of performance skills - Robert Mackie, Human Factors Research.

5. Training of Navy technical skills - Joseph Rigney, University of Southern California.

6. Instructional theory related to natural language communication Kenneth Wexler, University of California, Irvine.

These projects are discussed under the civilian activities section of this report.

CIVILIAN ACTIVITIES

The use of CAI in the civilian sector continues to grow and expand despite diminishing federal support (Grayson and Robbins, 1972). As in the military, many civilian applications have been rushed into fully operational environments without systematic empirical investigations of the assumptions underlying the implementations. With the notable exception of Merrill's (1973) discussion of the TICCIT approach, these assumptions are rarely explicated. However, as recent reviews have indicated (e.g., Jamison, Suppes, and Wells, 1974; Vinsonhaler and Bass, 1972; Vinsonhaler and Moon, 1973), significant and sometimes dramatic successes have been achieved using computers in education and training.

The reviews by Jamison et al. and Vinsonhaler and Moon are particularly extensive and are current as of early 1973. Conclusions from these reviews follow.

> "No simple uniform conclusions can be drawn about the effectiveness of CAI. At the elementary school level, CAI is apparently effective as a supplement to regular instruction. There are no examples yet of CAI's being introduced with a concomitant change in student-teacher ratio, which would, for example, cover the costs of CAI. At the present time, we can only conclude that CAI can be used in some situations to improve achievement scores, particularly for disadvantaged students.
>
> "At the secondary school and college levels, a conservative conclusion is that CAI is about as effective as TI (traditional instruction) when it is used as a replacement. It may also result in substantial savings of student time in some cases. Since the equal-effectiveness conclusion seems to be broadly correct for most alternative methods of instruction at the college level, there should be in the future increasing opportunities to experiment with selecting the method of instruction in terms of costs; and real opportunities should exist for substituting capital for labor, especially as the relative costs of technology in comparison to labor decline over the next decade." (Jamison et al., p. 55)

In discussing educational technology in general, Jamison et al. conclude with the following remarks:

> "First, we must examine if the savings in time exhibited in some of the studies using PI (programmed instruction) or CAI can be shown to be significant over longer periods and for a higher percentage of the total instructional program of students."
>
> "Second, we do not yet have an appropriately detailed evaluation of the impact of the various technologies on the long-term motivation of students.
>
> "Third, the long-term effects of individualization and the privacy of learning characteristic of some technologies also need more extensive evaluation. We do not know, for example, whether students who are given highly individualized programs in the elementary school for most of their instruction will strongly prefer the continuation of such methods

in secondary school and college or whether they will desire to return as they grow older to more traditional forms of instruction.

"Fourth, it has been indicated at a number of points in this review that most evaluations, particularly those considered well controlled, compare TI (traditional instruction) to a form of IR (instructional radio), ITV (instructional television), or CAI that closely emulates TI. It is at least plausible that many of the conclusions of this survey would be overturned were more imaginative uses of the media explored, which still permit comparative evaluation."

"Most of the educational technologies we have surveyed in this article have a relatively recent history. Even though there is already a fairly extensive literature on their evaluation, it would be a mistake to view the present state of that literature as anything but preliminary in nature. It will be many years before we have an adequately deep assessment of the strengths and weaknesses of the technological alternatives to traditional instruction that have been considered in this survey." (p. 58-59)

Vinsonhaler and Moon conclude their review with the following observations:

"1. There is a growing awareness of ERIC and other educational information centers. However, there still seems to be a slowness on the part of educators to use the services provided by such centers.

"2. An analysis of many studies seems to leave little doubt that when computer-administered drill and practice is used to augment traditional instruction in mathematics and language, the result is increased student achievement."

"3. Evaluation of computer-managed instruction systems used in elementary and high schools is limited. However, the results of studies that have been done generally show no significant difference between students in traditional programs and those in programs using computer-managed instruction. The crucial test will be whether improved versions of such systems will result in significantly better student achievement."

"4. There have been a number of major studies related to computer-administered counseling. These studies indicate that (a) students did not mind assistance by computers, provided that counselors were involved, and (b) in almost all programs, there appears to be no significant difference between computer-supported counseling and traditional methods.

Thus, economics and involvement of counselors become the important factors in determining if and when such systems should be used."

"In addition to conclusions suggested by evaluations of various applications, there are other observations that seem apparent to the reviewers. First, short-term, one-shot types of projects do not, on the whole, seem to show significant improvement over traditional ways of performing the same applications. Second, the success of educational systems applications appears to be increasingly less dependent upon hardware costs and existence of appropriate programming languages. Third .... there appears to be diminishing Federal support. Thus, projects started under Federal funds will need to meet sufficient local needs to obtain money from these sources. Fourth, there seem to be economic advantages to cooperative ventures that serve a number of users in a variety of educational applications. This allows the distribution of good software and systems development over a wide base and for more total utilization of equipment and facilities. Fifth, there are a number of applications that have been accepted as cost effective. Included are many appli-cations related to administration and the instructional appli-cation of test prepara-tion and scoring. Sixth, greater attention needs to be paid to human factors in the design and evaluation of many types of educational information systems applications." (p. 306-307)

The following four conclusions appear to be common to both reviews: (1) CAI is at least as effective as traditional instruction, (2) more experience is needed with improved and more imaginative applications of CAI, (3) the success of CAI appears to be increasingly less dependent for labor as the costs for technology relative to labor continue to decline, and (4) there is a need for long-term evaluations of sustained CAI projects.

Universities and Schools

University of Illinois - PLATO IV.

Although there is more curriculum material on the PLATO (Programmed Logic for Automatic Teaching Operation) system than on any other computer system, the PLATO project is probably best characterized as hardware development. The emphasis seems to be on developing a hardware system supported by appropriate software that will be sufficiently responsive to support a wide variety of CAI authors, techniques, and philosophies. PLATO is described below.

1. Hardware system. The PLATO IV terminal with keyboard, plasma screen, touch panel, random-access audio and rear-projection image-selector system, and the centrally located CDC 6400 computer system which

can support PLATO terminals have been described by Alpert and Bitzer (1970), Bitzer and Skaperdas (1971), Stifle (1971), Graham (1972), and NAVPERSR&D-CEN (Computer Applications, 1973). Notably, the number of terminals to be supported by the system has dropped from an initial estimate of 4000 to 1000. Large amounts of mass memory for PLATO IV are maintained by magnetic disks. Rapid information-transfer capability has been provided by extended core storage. The most recent development is a prototype auxiliary mass storage capability which can maintain a transfer rate of 10 million 60-bit words per second. (Demonstration and Evaluation of PLATO IV, 1974).

Terminals are linked to the central system through voice-grade channels. Recent equipment development has made it possible to service four PLATO terminals with one full-duplex telephone circuit. Cost of such arrangements includes an installation fee and a monthly line cost. This type of communication is active 24 hours a day on a dedicated-line basis. Recent efforts to reduce the communication cost have considered omnidirectional microwave, a technique that could cost as little as 40% of the telephone transmittal rate.

2. Software. The computer language for PLATO is called TUTOR. Two recent users manuals were authored by Ghesquiere, Davis, and Thompson (1974) and by Sherwood (1974). TUTOR is a powerful language, relatively easy to learn. Linear and simple branching CAI lessons, without graphics, can be coded at a terminal with only a few hours of study. Originally planned as a higher-level, CAI author language, TUTOR has continued to expand and change. At the more complex levels of coding, it now resembles a stanhas become too complex, that the number of commands is excessive, and that keeping track of all contingencies while coding is almost impossible. On the other hand, this same complexity has made TUTOR extremely flexible and useful for simulation and gaming.

There is a current controversy over the best and most useful way to accomplish PLATO coding. Two points of view are: (1) the lesson-author must learn TUTOR and code his own materials, and (2) the lesson-author must be familiar only with the capabilities and limitations of the language, with coding and entry being accomplished by a separate person who is a TUTOR language specialist. Both methods are currently being evaluated.

3. Courseware. The number of lessons available on the PLATO system continues to grow. The latest documentation by Lyman (1974) lists 50 subject-matter and curriculum areas. A listing of the number of lessons, lesson file names, and lesson descriptions is not available. A general discussion of the interaction of PLATO instruction with classroom instruction was presented by Davis (1974).

4. Civilian application areas. In January 1972 the National Science Foundation (NSF) awarded a contract to the University of Illinois to develop and demonstrate the classroom use of PLATO in both elementary schools and community colleges. Approximately 11 elementary schools in the Urbana-Champaign School Districts of Illinois and five community

colleges in Champaign and in Chicago are participating. Educational Testing Service (ETS) was awarded a separate contract by NSF to evaluate the technical cost and educational effectiveness of the system (Alderman and Mahler, 1973; Breland, Amarel, and Swinton, 1974). Final classroom demonstrations are scheduled for late 1975 or early 1976.

5. Military applications areas. ARPA initiated a tri-service evaluation of the educational and economic effectiveness of PLATO IV in several military training sites in August 1972 (Demonstration and Evaluation of PLATO IV, 1974). The period of evaluation runs through June 1975. ETS has been contracted by ARPA to perform a separate evaluation of the military efforts.

The Army has test sites at the U. S. Army Signal Corps and School, Fort Monmouth; U. S. Army Ordance Center and School, Aberdeen Proving Grounds; Army Research Institute; and Human Resources Research and Development Organization. The Navy has test sites at NAVPERSR&DCEN, San Diego and at the Navy Training Equipment Center, Orlando. The Office of Naval Research has sites at the RAND Corporation, University of Southern California, and Stanford University. The Air Force has test sites at Chanute Technical Training Center, Chanute Air Force Base; School of Health Care Services, Sheppard Air Force Base; and the Air Force Human Resources Laboratory Lowry Air Force Base. The first annual report on the military effort has recently been completed (Demonstration and Evaluation of PLATO IV, 1974).

Chicago Public Schools.

The largest CAI effort in the world in terms of number of terminals on a single system and number of students receiving daily instruction is also in Illinois. The Chicago Public Schools, under the direction of Harry Strasburg, currently maintains a 400-terminal UNIVAC 418-III system that will be expanded to support 800 terminals in 1975-76. This system provides CAI in reading, mathematics, and language arts to more than 5000 students each day. An overall description and evaluation of this project has not yet been published. The curriculums used were developed by Computer Curriculum Corporation, Palo Alto, California.

Brigham Young University - Time-Shared Interactive Computer-Controlled Information Television - (TICCIT).

TICCIT is a joint development of the MITRE Corporation and Brigham Young University (BYU). As described by Bunderson (1973), NAVPERSR&DCEN (Computer Applications, 1973), and MITRE (Toward a Market Success for CAI, 1972), MITRE's responsibilities are to design and implement the TICCIT computer operating system, and BYU's responsibilities are to develop TICCIT courseware. Currently four sites are scheduled to use the TICCIT system: BYU, Provo, Utah; Phoenix Junior College, Phoenix, Arizona; Northern Virginia Community College, Alexandria, Virginia; and the Naval Air Station, North Island, California. The Provo, Phoenix, and Alexandria installations were scheduled for full operation in Fall 1974, and the North Island installation was scheduled for full operation in Winter 1975.

Despite MITRE's responsibility for implementing the TICCIT operating system, many of the unusual design specifications for this system have come from the approach to lessonware preparation developed at BYU. This approach has been discussed by Merrill and Boutwell (1973), Bunderson (1973), NAVPERS-R&DCEN (Computer Applications, 1973), and Merrill (1973), and will not be detailed here. Notably, the TICCIT project has attempted to develop a comprehensive multimedia plan for lessonware preparation not limited to, nor solely motivated by, the use of computers.

Merrill (1973) discussed four aspects of TICCIT that make it unique among CAI projects:

1. Open box vs. built-in strategy. "The TICCIT System was designed to have a built-in strategy. The author ... is responsible for supplying the content but does not have control over program strategy." (p. 1)

2. Learner content control vs. learner strategy control. "The TICCIT system was designed to allow both content and strategy control. Not only can the student decide what he wishes to see next ..., but he can also decide what types of presentation mode he wishes to receive as well as to determine the sequence of presentations related to a given piece of content." (p. 2)

3. Adaptive system vs. adaptive students. "The primary meta-objective of a CAI system ought to be to make students system-independent. Any student which [sic] learns some content on such a system should learn how to learn with or without a system." (p. 3)

4. Authoring languages vs. natural language authoring. "Because the strategy is built into the TICCIT system, it is feasible to have authors prepare materials in natural language. They are constrained in that they must prepare certain types of displays, but these correspond very closely with those that occur in non-CAI instructional situations." (p. 4)

Stanford University.

There are three aspects to this project: (1) computer-assisted instruction in computer programming, (2) use of linked images as a mnemonic procedure for learning foreign language vocabulary, and (3) investigations of optimal teaching strategies.

The computer programming course provided instruction in Algebraic Interpretive Dialogue (AID) by presenting frame-oriented CAI and by giving students access to an AID interpreter. Students could switch between the CAI material and the AID interpretor at will. During the 1972-73 and 1973-74 school years, this course ran at DeAnza Junior College and at the University of San Francisco. This work was documented by Beard, Lorton, Searle, and Atkinson (1973), Friend, Fletcher, and Atkinson (1972), and Friend (1973). Emphasis has shifted in the 1974-75 school year to a more sophisticated instructional program in BASIC, documented by Barr, Beard, and Atkinson (1974). The goal of this program is to increase the sophistication with which the instructional program monitors a student's work and responds to it with appropriate hints and prompts by maintaining within the computer a model of the subject matter and a history of his interaction with it. A major aspect of this work is the use of algorithms for judging the semantic correctness of student programs.

Other ONR-sponsored research is evaluating the effectiveness of mnemonic procedures--the keyword method--for learning a foreign language vocabulary. This method requires associating the foreign word with an English word that sounds like part of the foreign word and forming a mental image of the keyword interaction. It is hypothesized that the keyword method could be used in a special computerized vocabulary program to supplement the introductory language course. This could provide the student with an individualized procedure for rapid expansion of his vocabulary. This work has been documented by Raugh and Atkinson (1974), and Atkinson and Raugh (1974).

ONR-sponsored research investigating optimal teaching strategies in CAI has been documented by Atkinson (1972, 1974), Atkinson and Paulson (1972), Chant and Atkinson (1973), and Paulson (1973). This work has progressed from applications in simple paired-associate learning paradigms to optimal strategies for item and subject heterogeneity, item and subject interactions, allocation of time among interrelated subject matter components, and pre-specified distributions of student achievement.

Under the auspices of the Institute for Mathematical Studies in the Social Sciences, Professors Atkinson and Suppes at Stanford have achieved major advances in CAI. Other recent projects at the Institute include a large CAI network of schools for the hearing-impaired (Fletcher and Suppes, 1973; Suppes and Fletcher, 1974), use of digitized audio in initial reading instruction (Atkinson and Fletcher, 1972), use of teletypewriter-based tutorial dialogue in CAI in logic (Goldberg, 1973), use of spoken tutorial dialogue in CAI in logic (Danforth, Ragosa, and Suppes, 1974), use of continuously monitored models of mastery in CAI (Suppes, Fletcher, and Zanotti, 1973a, 1973b), and cost-performance consideration in CAI (Ball and Jamison, 1973; Jamison, Fletcher, Suppes, and Atkinson, 1974).

Florida State University.

The Center for Educational Design at Florida State University (FSU) is acquiring a PLATO IV system. An initial installation of six terminals is expected by August 15, 1975. These six PLATO terminals will be interfaced with a buildup of 32 per year for five years to a total of 160 terminals. The system will be used primarily for CAI, with 100 full courses planned within seven years.

Currently FSU operates a CMI system on the CDC 6500 of the University Computing Center, with a student load of about 2200 students. The PLATO system and the CDC system will be linked and will share storage. If the PLATO system CPU is down, the CDC 6500 will take control to service CAI with priority over any other operations of the FSU Computing Center. No CMI is planned for the PLATO system.

CAI under development at FSU is, by requirement of the Center for Educational Design, produced under a systematic approach. Development involves a team of CAI, subject matter, and instructional design experts. All CAI will be instructionally validated to determine that objectives are met. It is anticipated that as many as 48 courses will be undergoing instructional development at any given time. The motive for such large-scale CAI service at FSU is to improve instruction by providing more individuals with more instructional resources. The system will be available to students 24 hours a day, supplementing lectures and other media more restricted in access.

University of Texas at Austin.

The University of Texas has a long history of CAI development. There are three aspects of recent work.

1. Implications of learner control for student affect. This work involved two investigations: (1) an affective evaluation of student control, and (2) the extent to which effective use of learner-control can be related to cognitive and affective individual differences.

2. Computer-managed instruction. This work compares CMI with traditional classroom approaches for presenting instruction in undergraduate teacher-training.

3. Detection and reduction of test anxiety. CMI involving video tapes, modeling, reading, and CAI was used to reduce test anxiety. A notable result was that CMI by itself did not reduct test anxiety, but that personal contact used with CMI produced a substantial reduction.

Pennsylvania State University - Computer Assisted Renewal Education (CARE).

The CARE project uses college-level CAI to train regular classroom teachers to recognize the characteristics of handicapped children, to decide whether specific handicaps are sufficiently severe for referral to an educational specialist, and to provide diagnostic-prescriptive teaching for preschool and primary children who are handicapped but who are assigned to regular classrooms. There is a current effort to "mainstream" handicapped children--i.e., leave them in regular classrooms whenever possible. This effort has created a national need to train the increasingly large numbers of regular classroom teachers who are not special educators, but who have handicapped children in their classes. Rather than provide mobile teams of instructors or require teachers to attend the Pennsylvania State University (PSU) campus for the 3 to 9 credit hours of instruction needed to update regular teacher training, PSU has been providing the necessary instruction for university credit with self-contained CAI delivered to various sites in mobile vans. The only operational requirement for these vans is an adequate power supply; instruction is delivered on IBM 1500 instructional systems completely contained in the vans. Four courses are currently being offered by the CARE project, and two more are being prepared for the 1975-76 school year. An evaluation of a portion of the CARE curriculums was documented by Cartwright, Cartwright, and Robine (1972). More recent documentation of CARE was presented by Hall, Cartwright, and Mitzel (1974).

Massachusetts Institute of Technology--TURTLE.

The TURTLE project, directed by Seymour Papert, has not had a major impact on CAI in terms of numbers of students, terminals, or amount of funding. Papert's philosophy is beginning to affect many CAI projects. This philosophy has not been expressed in a coherent and concise manner. Basically, it emphasizes "creative functions" of a subject rather than rote aspects. Rather than teach about some subject matter, we should provide environments in which learners can experiment with what the subject matter lets them do. Minsky (1970) has stated some basic notions of this approach:

> "--To help people learn is to help them build, in their heads, various kinds of computational models.
>
> --This can best be done by a teacher who has, in his head, a reasonable model of what is in the pupil's head.
>
> --For the same reason the student, when debugging his own models and procedures, should have a model of what he is doing, and must know good debugging techniques, such as how to formulate simple but critical test cases.
>
> --It will help the student to know something about computational models and programming. The idea of debugging itself, for example, is a very powerful concept — in contrast to the helplessness promoted by our cultural heritage about gifts, talents, and aptitudes. The latter encourages, I'm not good at this, instead of, How can I make myself better at it?
>
> These have the sound of common sense, yet they are not among the basic principles of any of the popular educational schemes such as operant reinforcement, discovery methods, audio-visual synergism, etc. This is not because educators have ignored the possibility of mental models, but because they simply had no effective way, before the beginning of work on simulation of thought processes, to describe, construct, and test such ideas." (p. 48)

Generally, this project teaches children a version of computational geometry called TURTLE geometry. Instead of using a compass and straightedge to draw geometric figures, students are taught to use, and are encouraged to experiment with, a programmable device (the TURTLE) that maneuvers about on paper with its pen up or pen down drawing figures. In effect, children experience some of the creative aspects of geometry by learning to program. It is doubtful that TURTLE geometry will have a major impact on military training, but the impact of Papert's approach is already being felt.

University of Southern California (USC).

This project is directed by Joseph Rigney and is funded by ONR. It is investigating the use of CAI to provide hands-on training for operator and maintenance personnel by using adaptive, computer-based systems to simulate equipment. The CAI system uses graphics terminals with animation capabilities, random-access slide projectors under computer program control, and front-panel simulators with controls and displays on-line to sense control positions and to simulate display outputs. Recent documentation of this work has been provided by Rigney (1973) and by Rigney, Towne, and King (1974).

Information on the TASK TEACH project at USC was included in Computer Applications (1973), and will not be repeated here. Rigney and Towne (1974) summarized this project.

University of California at San Diego (UCSD).

Sponsored by ONR, Donald Norman and his associates at UCSD are developing a network model for human memory (Norman, 1973; Norman, Gentner, and Stevens, 1974). The goal of this project (STATNET) is to develop a computer model of a tutor that will answer questions and give remedial instruction in prescribed topics of statistics. The instructional language in STATNET is natural English. The model is being developed by observing student-tutor communications restricted to typewriter terminals. The system cannot yet process all student structured queries. The memory model is being modified to provide appropriate data base definitions.

The goal of another project, FLOW, is to develop an automated system to teach a simple language and, in the process, to study the learning of concepts and procedures. FLOW is investigating how the computer must model the student in order to provide effective interaction.

University of California at Irvine (UCI).

Under ONR funding, Hamburger and Wexler are investigating the theoretical bases for a reading program for functionally illiterate young adults, and will test the program experimentally. The goal is to improve the performance of Navy recruits who cannot read sufficiently well to benefit from technical training. Expected products are a theory of reading and orthography learning, and identification of potential computer applications in the tutorial process. The most recent documentation of this work was provided by Hamburger and Wexler (1973).

The Physics Computer Development Project directed by Alfred Bork and funded by the National Science Foundation is also located at UCI. This three-part project is based on software facilities already developed by Bork and his associates. Part I will provide a series of "interactive worlds" programs, which supports free interaction by students with a variety of phenomena. Part II involves remolding the beginning physics course around the computer development project. Part III will investigate ways to provide access to the project materials for other schools. This work is expected to form a basis for a proposed Educational Technology Center at UCI.

Industrial

Bolt, Beranek, and Newman (BB&N) - SCHOLAR and SOPHIE.

The BB&N SCHOLAR project, directed by Collins, is sponsored by ONR and was discussed by NAVPERSR&DCEN (Computer Applications, 1973). The project is investigating techniques for maintaining a tutorial dialogue in English between a student and a computer model of a specific subject area (Collins, Warnock, and Passafiume, 1974). These techniques have been characterized as "mixed initiative" because dialogue exchanges can be initiated either by the student or the computer. What information is presented by the computer depends on the model of the subject matter and on the depth of information already covered by the student. The original system to teach geography is being extended to embody various tutorial strategies.

Another system, called NET-SCHOLAR, has been developed to teach the use of the ARPA computer network. NET-SCHOLAR can provide descriptional, functional, and procedural information, whereas the previous SCHOLAR systems dealt only with static information (Grignetti and Warnock, 1973).

Other work at BB&N, directed by John Seely Brown and supported by the Air Force Human Resource Laboratory, is a system termed SOPHIE. Like SCHOLAR, SOPHIE attempts to endow a CAI system with some of the symbolic knowledge, problem-solving strategies, and natural-language capabilities of a human tutor. Unlike SCHOLAR, SOPHIE uses several representations of subject matter and has inferencing procedures designed for each of these representations. The system contains an English language processor, a semantic interpreter, an electronic circuit simulator, and a semantic network. SOPHIE can randomly generate an easy or hard fault in a simulated circuit. The student can then ask, in English, for measurements at any test point in the circuit. The computer cannot only provide the student with simulated measurements, but it also can query him about his hypotheses and check whether they are consistent with information previously given. This work has been documented by Brown, Burton, and Bell (1974).

Human Factors Research, Inc.

Human Factors Research, under the direction of Robert Mackie, is investigating the possibilities of training in digital electronics, using inexpensive computer simulations of equipment rather than the equipment itself. To measure the effectiveness of this method, performance by students who used computer-driven laboratory displays was compared with performance by students who received similar instruction using hard-copy diagrams and programmed texts. This work is documented by Dick, Royal, Simpson, and Mackie (1974) and is funded by ONR.

Hewlett-Packard.

Despite the early lead provided by IBM in developing the 1500 Instructional System, the innovative work supported by Xerox Research Corporation, and the major marketing efforts of other computer companies, the most common CAI systems currently in use are Hewlett-Packard time-sharing systems supporting Model 33 teletypewriters. Informal information indicates that there are 6000 to 7000 such terminals currently in operation. Hewlett-Packard markets standard timesharing systems that support BASIC and include CAI software packages as purchasable options. Almost all of these CAI packages were prepared by Computer Curriculum Corporation (CCC) of Palo Alto, California. The strength of the Hewlett-Packard systems may be their flexibility. They can be used simply as delivery devices for the CCC curriculum packages, and/or they can be used by students, teachers, and school administrators as standard resources for timeshared computing.

An important development by Hewlett-Packard has been the Instructional Dialogue Facility (IDF) (Instructional Dialogue Facility, 1973). IDF provides authors with a prompting technique for entering CAI. An author need do nothing more than answer a series of computer-initiated questions to produce substantial amounts of CAI. He looses considerable control over how his material is presented, but he needs to know very little about the conventions (e.g., programming and coding languages) ordinarily used for communicating with computers.

Xerox Palo Alto Research Center.

This center is a research and development project of Xerox Data Systems. Researchers at the center have not had a major impact on CAI, but their efforts are notable for what they are trying to develop, namely the Dynabook. The Dynabook is a notebook-size, battery-operated computer system that communicates with its display screen at a rate of about 3.5 million baud, supports sophisticated computer graphics such as animation with color, and markets for about $1,000. The Dynabook may never be fully achieved, but succesive approximations to it will be progressively interesting.

Computer Curriculum Corporation.

Most of the CAI currently in use by primary and secondary schools was developed by Computer Curriculum Corporation (CCC). The intent of CCC curriculums is to appropriately supplement classroom presentations. These curriculums emphasize drill and practice aspects of various subjects to free teachers for more creative aspects of instruction. The student terminals required by CCC curriculums are teletypewriters or alphanumeric cathode-ray tube displays. In addition to the elementary and secondary school curriculums, CCC has developed a variety of remedial instruction for adults, such as preparation for GED examinations, and arithmetic, reading, and language arts for adults.

SYSTEMS DEVELOPMENT

The systems activities that most directly affect CAI concern the development of computer terminals and communication techniques. Although improvements in main-frame hardware, memory, and peripheral storage may provide major breakthroughs with immediate implications for CAI, the gradual development of terminals and communication techniques continues to hold current relevancy for reductions in costs and increases in efficiency. Several technological developments concerning CAI terminals and communication have reached a level that makes their probable impact on CAI imminent and likely.

Student Terminals

An ideal display system that fulfills current educational needs may be a single inexpensive storage unit for all media. Such multi-purpose storage devices seem to be on the threshold of reality. The ultimate may be a unit, currently planned for production within a few years, such as a mylar video disk which uses a laser readout of up to six hours of video and audio.

At present, however, the most common student terminals used for CAI are teletypewriters. The limitations of these devices are sufficiently notorious to obviate the need for further review. However, the low cost of teletypewriters has consistently overridden objections to their use. This cost is no longer as inexpensive relative to other computer terminals, as it once was. The state-of-the-art reveals at least four terminals that are becoming increasingly attractive as their costs continue to decrease. One of these, the plasma terminal developed by the University of Illinois, has already been discussed in connection with the PLATO project and the Air Force AIS project. The remaining three are discussed below.

Lincoln Laboratories.

Development of the Lincoln Training System (LTS) began at Lincoln Laboratories, Massachusetts Institute of Technology, Lexington, Massachusetts, in 1969, under the direction of F. C. Frick. Progress reports on LTS are published quarterly by Lincoln Laboratories Technical Summaries. Goals and directions of the project were discussed by NAVPERSR&DCEN (Computer Applications, 1973). The prototype LTS-3 terminal and the LTS-4 terminal under current development were described by Dossett (1972). Several feasibility studies of LTS have been performed at Keesler Air Force Base (A Comparison of Hardware vs. "Courseware", 1974; Keesler Test of Lincoln Training System, 1972; Training High-aptitude Self-paced Students, 1972).

LTS represents a major engineering effort to develop a computer-controlled, audio-visual terminal that presents instruction with microfiche projection and audio, allows limited student interaction, and records student performance data. Microfiche projections are usually photographs of drawings, figures, printed instruction, and questions. Student responses and interactions with the instructional material are limited to multiple-choice items of up to 10 selection items and numerical, constructed answers. Function keys include: (1) CLEAR, to erase erroneous response; (2) HELP, for special material (when available); (3) REPEAT, for audio; (4) GO-ON, to terminate a frame; (5) BACK and FORTH, to skip material recently covered; and (6) INDEX, to access a table of lesson entry points. Branching is limited to differential responding--i.e., the student's specific answer choice can be used to branch him to different sequences and/or different feedback statements.

Unique in the LTS engineering development is a nonstandard film card (microfiche) that contains 12 visual displays with corresponding audio records. The audio record for each image is stored in the form of a wide-modulated spiral sound track with a maximum duration of 28 seconds at frequencies of 300 to 3000 Hz, and tracked and read by photo diodes.

Several prototype LTS-3 terminals have been constructed and used to validate the LTS concept in an operational training environment. The terminal used a commercially developed card reader modified to incorporate the audio assembly, which consists of a "needle" which rotates around the stationary record in the spiral path. Each reader contains a tray which holds up to 750 microfiche cards (with 12 images and corresponding audio messages per/card) that are readily accessed by the computer as it processes student responses. A minicomputer was configured to control and record student responses for five student terminals.

Most current effort concerns engineering development of the prototype LTS-4. It is intended to be a stand-alone, "intelligent" terminal, superior in design and flexibility to the LTS-3, and not requiring an external computer. The LTS-4 will contain its own logic and memory circuits for processing microfiche-bound logic and student responses. The LTS-3 750-capacity microfiche tray will be replaced by a cartridge containing up to 30 fiche cards, that provide 360 images and audio messages. Estimates in 1972 indicated the LTS-4 unit might be produced for $2,000 in mass production.

A problem inherent in LTS audio-visual display and storage is the custom-designed equipment required for producing the visual and audio recordings. Editing and revision require remaking the entire film card. Other problems are associated with mechanical random access of the images and with [illegible]st and fingerprints that degrade audio quality. Further questions regard the timeliness of the LTS six-year development program and current state-of-the-art developments in newer and more flexible delivery system technology--for example, video-disk storage devices for audio and for stationary and moving visual displays, which are randomly accessible and controllable by mini- and microcomputer.

Human Resources Research Organization.

The color, sensitivity, resolution, and response characteristics of human visual perception determine the design limit of a display terminal. However, because higher costs have been associated with greater performance and because R&D funds have been limited, off-the-shelf terminals have fallen short of both design and technical limits. An attempt to close the gap between feasibility and availability has produced the CHARGE terminal system. CHARGE terminals are intended to approach the design limit without accompanying high costs.

The design of the CHARGE terminal had to solve two problems: (1) how to buffer a high resolution colored image, and (2) how to decode and display the image on a CRT. Both problems required a low-cost solution. The solution to the buffer problem is similar to that used in strobe terminals for line grap.. c images--encode the image, rather than buffer the video. The solution differs, however, in that no limit in the number of future elements, called edges, ensues, as in the case of strobe terminals where large numbers of lines cause an objectionable flicker. An EDGE-encoding technique permits a 4 by 10 bit image to be displayed at the cost of a 1/4 by 106 bit buffer e key to a low-cost terminal.

The solution to the refreshing (decoding) problem required innovative memory architecture and data organization, as well as innovative hardware, in order to generate video for output on a color monitor without significant restraints in image complexity and resolution. The image generator is a fast, intelligent data translator located in the output data path linking the central computing system to the display terminals. Input data from the central computing system are (1) world description, a complex symbolic description of a region of finite three-dimensional space, and (2) viewing parameters, defining an observer with respect to this world.

The terminal has been built and debugged. The image generator exists only as a FORTRAN package. Work has begun on the design for a hardware solution. The image resolution at the terminal is 1600 horizontally and 1200 vertically, using a 5-to-1 interface raster scan. The 1200 vertical resolution was used to eliminate staircasing for nearly horizontal edges. A new design will attempt to eliminate staircasing at 480 vertical resolution, by smoothshading horizontally at the stairs. Specifications presently require a 5000-edge picture to be generated in 1/30th second at a cost of $20,000 for parts and 2.7 man-months for personnel.

NAVPERSR&DCEN - Computer-Controlled Multimedia System.

The Computer-Controlled Multimedia System, $(CM)^2S$, combines the functional characteristics of many educational media devices, and channels each media type to one receiving source in an interactive mode. The system is being developed to provide instructional capabilities not currently available. The educational needs for $(CM)^2S$ are related to three factors in effective learning situations: (1) interaction, (2) multimedia environments, and (3) individualized instruction.

Instructional effectiveness depends in part on a student's opportunity to practice, obtain further information, receive remedial instruction, receive feedback, and obtain appropriate instruction for his current level of knowledge. With the exception of computer-assisted instruction, educational media do not allow real-time interaction.

A second educational need is a learning environment that presents information in various media. Educators recognize that different media (e.g., visual stills or motion pictures, auditory messages, and tactile information) are appropriate for different learning situations and different people. The capability to mix multiple-media sources is a prime characteristic of $(CM)^2S$.

The third educational need is to allow alternative selection of media for presentation. The display system will allow this individualization of instruction.

The design of $(CM)^2S$ allows information from several media sources to be channeled to a single receiving unit. The single receiving units, raster-scan display terminals, allow use of broadcast and closed circuit television as well as media under computer control. In an on-line mode, a switching unit channels the different information sources. Sources include: (1) a video disk which displays color still frames or short sequence motion where the motion rate may be varied, (2) a color video tape player which can be started, stopped, or reversed under manual control and can transmit frames to the video disk for storage, (3) a bank of audio cartridges which may be accessed to provide messages or narration to accompany visual media or may be used separately, (4) an audio component which generates speech from disk-stored digital codes, and (5) computer generated alphanumerics and graphics. Input devices include a keyboard for alphanumerics, with special function keys to control the multimedia invironment (such as freezing the video tape on a single frame for study), sonic pen, graphic tablet, and touch panel.

Communication Techniques

Factors that are often overlooked in considering the costs of CAI are those encountered in communicating among student terminals, central computing facilities, and data-storage facilities. Computer net works, cable television, and satellite communication have all been suggested as possibilities for reducing this cost.

Computer Networks.

A computer network is an interconnected set of dependent or independent computer systems which communicate with each other in order to share resources such as programs or data, or for load sharing and reliability reasons. Several examples of commercial, military, and academic application of networks were discussed by NAVPERSR&DCEN (Com puter Applications, 1973). The state-of-the-art can be suggested by the advantages and problems experienced by institutions attempting to apply this technology to education.

In 1973, the School of Basic Medical Sciences of the University of Illinois at Urbana-Champaign (SBMS-UC), received a three year grant from the National Institute of Health for developing a computer-based education (CBE) program within the school's curriculum. Hody (1974) stated that "One of the most compelling advantages of CBE is that instructional materials can be widely shared among a large group of users ... One might then expect that medical CBE would be widely used in American medical schools, but in fact it is still highly experimental and to a large extent unsatisfactory and suspect" (p. 243). Hody cited five problem areas: (1) the incompatibility of hardware, computer languages, and course organization, (2) poor lesson quality for lack of standardized design and review procedures, (3) poor accessibility to catalogues, (4) redundancy of coverage in topical areas and poor coverage in others, and (5) student frustration with system malfunctions and bizarre requirements for interaction.

To overcome these problems, SBMS-UC is sponsoring a mini-network on the PLATO IV system. The University of Illinois Colleges of Medicine at the Medical Center (Chicago), Peoria, and Rockford will participate. Five other medical schools will be chosen from among those applying for membership. SBMS-UC will provide: (1) the PLATO IV system, (2) programming standards, lesson planning, review and evaluation procedures, (3) a catalogue for scheduling lesson development involving member schools in lesson writing and review, (4) a panel of professors, students, and medical practitioners as consultants, and (5) a pool of medical students for a material test group.

Another network, specializing in teaching the medical sciences, is sponsored by the Lister Hill National Center for Biomedical Communications, National Library of Medicine. Rehkopf and Katzin of the Department of Opthalmology of the University of Pittsburgh, which has joined the network, acknowledge many of the problems noted above, but write enthusiastically of the advantages. "With the availability of teaching material on an existing communication network, we have been able to use CAI in an actual teaching situation, evaluate CAI teaching techniques and develop some expertise of our own without a great deal of time, difficulty and expense. Without this experience, our faculty and staff would certainly not have developed the enthusiasm to make such an early commitment to authoring of CAI material" (Rehkopf and Katzin, 1974, p. 138).

Similar pro and con opinions are expressed by members of the Michigan Educational Research Information Triad (MERIT) network (Fischer, 1974). MERIT is a cooperative effort of Michigan State University, Wayne State University, and the University of Michigan. The intent of this project is to create an educational network for sharing computer resources at member schools. Effective resource sharing requires that arbitrary processes in arbitrary hosts easily interact across the network. At present a user must know something about the operating procedures of his own system plus those of the system he wishes to contact. This is a distinct disadvantage for the average user, and it will be alleviated by the network-file access system which is now being designed. The user will then need to understand his own system only. MERIT publishes catalogues of programs and data available on the network, but these are of limited value until the file-access system is operative.

Computerized Cable Television.

Computerized cable television was reviewed by NAVPERSR&DCEN (Computer Applications, 1973). A few cable-TV firms have experimented with two-way systems that connect private homes to a computer center. A demonstration of a subscriber response system was to be launched in March 1973 when two-way terminals were to be installed in 1000 of the 6000 homes in El Segundo, California. The experiment was to be jointly conducted by Theta Comm of California and Theta Cable. Theta Comm has since moved to Arizona, with its future in some doubt, but the project is still active, though on a less ambitious scale. Ten two-way sets have been installed in homes of employees of Theta Cable. Demonstration films are available, but technical problems remain to be solved.

Ball and Eller (1974) documented a number of technical and economic considerations in using cable-television distribution facilities and computing equipment to support interactive television systems in the home. Three levels of interactive system design were used to explore experimental cost/service ratios: (1) a subscriber system in which every effort is made to reduce equipment levels while maintaining a semblance of interactive use, (2) a timesharing computer system capable of providing curriculum, social, and commercial services to about 90 simultaneous but independent users, and (3) a timesharing computer system as just described, but with home-refresh capability which reduces channel requirements and the need for segmenting the cable-TV system and which permits the full frame capacity of a video channel to be used.

Satellite Communication.

Satellite communication was reviewed by NAVPERSR&DCEN (Computer Applications, 1973), and Polcyn (1973, 1974a, 1974b). Papy and Polcyn (1973) discussed current and planned experimentation in the educational potential of satellite communication. Economic aspects of satellite communication for CAI were discussed by Ball and Jamison (1973) and by Jamison, Fletcher, Suppes, and Atkinson (1974). Both of these papers suggest favorable economic arguments for CAI delivered by satellite when instruction must be delivered to dispersed populations.

The National Aeronautics and Space Administration is alloting broadcast time for experiments on its Application Technology Satellites, Series 1, 3 and 6 (ATS-1, ATS-3, ATS-6). Several major experiments have been conducted or are now in progress.

The state of Alaska used ATS-1, in 1970-71, to link 21 villages by providing two-way radio communication for inservice teacher training and student contact with outside educators. Alaska is now engaged in a more ambitious experiment with the ATS-6 Satellite which can broadcast a much stronger signal. Broadcast time is being divided between education and viewer-defined programming service. One-way video, two-way audio, and teletypewriter capabilities are included in the educational program. Some CAI will be tried for mathematics and language skills in grades 1-6. The programming service has designed pause points into the video, allowing viewers to use the interactive audio to ask questions, express opinions, or suggest topics to be covered in subsequent programs.

The University of Hawaii is using ATS-1 for exchange of voice, teletypewriter, and facsimile information with its campuses and other English speaking universities in the Pacific Basin.

Brazil used ATS-3 for preliminary experimentation with two-way voice, one-way television, and two-way teledocumentation which incorporated Xerox equipment at the terminals. Brazil is now using ATS-6 in a four-year experiment involving 600 schools. The current emphasis is on teacher training, but will shift to student education later in the program.

The Rocky Mountain Region experiment is using ATS-6 broadcast capabilities in three combinations: (1) one-way video with one-way audio/digital, (2) one-way video with two-way audio/digital, and (3) two-way video with two-way audio/digital. Sixty sites are located throughout the eight-state area in which the target audiences are individuals of different cultural and ethnic backgrounds. Adults involved with preschool children or adolescents interested in choosing a career are of primary concern. Questions to be answered are:

a. What degree of learning is facilitated in each target audience by various media mixes, associated programming, and support patterns?

b. Which media mix, associated programming, and support patterns solicited what degree of participation by various target audiences?

c. What are the costs associated with questions 1 and 2, and what are the implied cost/effective alternates and trade-offs?" (Polcyn, 1973, p. 48)

The Appalachian experiment is using ATS-3 and ATS-6. Delivery patterns are: (1) one-way TV alone, (2) two-way interactive audio and teletypewriter communications with delayed feedback for CMI, (3) two-way interactive audio and teletypewriter communication with immediate feedback for CAI, and (4) two-way interactive audio and teletypewriter communication with immediate feedback and one-way TV.

In 1975, ATS-6 will be swung into a new orbit for an experiment in India. It is estimated that 40,000 to 50,000 villages will be involved in programming designed to contribute to family planning objectives, improved agriculture practice, and a sense of national integration.

CURRENT ISSUES IN INSTRUCTIONAL DESIGN

Issues in CAI are complicated by competing interpretations of what CAI should do. There is as much energy expended on discussing the role of CAI as there is on developing CAI techniques. The following issues were selected because they are currently receiving substantial attention.

Computer-Managed Instruction (CMI)

In Computer-Managed Instruction (CMI), the bulk of training is normally off-line, although some of the instruction may be computer-based simulations, computerized drill and practice, or other forms of interactive CAI. CMI provides two basic functions: (1) support for individual students, including diagnostic testing and training prescriptions based on the tests, and (2) support for training managers, which may include scheduling students and resources, keeping records, predicting student throughput time and achievement, and analyzing test and training data. Testing may be either off-line, with input to the computer from an optical scanner or from conventional means, or on-line, using an interactive terminal. The latter increases the capabilities for diagnostic testing and specialized remediation, but may not be cost effective for many applications because of the larger number of terminals required.

There is a variety of research, development, and implementation effort in the three services which include CMI. The Army Computerized Training System (CTS) and Air Force Advanced Instructional System (AIS) will have CMI capabilities. The Computer-Assisted Instruction Study Management System (CAISMS) sponsored by NAVPERSRANDCEN also includes both CAI and CMI.

A six-month analytical survey and study was conducted by the Training Analysis and Evaluation Group (TAEG) of the Naval Training Equipment Center. The principal conclusions of the study (Middleton, Papetti, and Micheli, 1974) are quoted below:

> "a. There is no alternative for the Navy but to go to CMI if any significant number of its over 4,000 courses are to become self paced and individualized (which is the trend of current educational technology)." (p. 63)
>
> "b. Preliminary tradeoff analyses made during this investigation reveal that a combination of minicomputers (strategically located to perform the routine tasks of CMI) and a central computer system (for high level management

information processing) is more cost effective than a single large-scale centralized computer." (p. 63)

"c. A minicomputer for small, remote classes is feasible.... it is proposed that CMI training in remote sites be linked together via land lines. In this concept, a greater number of managers and students can utilize the capabilities of CMI and have a more cost-effective system." (p. 64)

"d. The use of shipboard tactical computers for managing individual training has long been desired by the training community. However, numerous technical and logistical problems, as well as priorities placed upon the use of shipboard computers by higher authorities, have allowed relatively little training via operational computers aboard ships .... the state-of-the-art is advancing at such a pace in the mini- and micro-computer field that in the near future the market price for these systems will be such that it will be economically more advantageous for ships to have a dedicated system for education, rather than implementing a retrofit program to use operational equipment and computers for CMI." (p. 64-5)

Although CAI manages instruction, and CMI can easily include CAI, CAI and CMI are occasionally presented as competing applications. Given fixed resources and a specific application, a choice between interactive computerized instruction by itself and computer management of all aspects of the application might be necessary. However, the state-of-the-art provides no general solution to this problem. The best choice in any situation will depend on characteristics of the specific application. It is clear from the achievement gains reported by Suppes et al. (1973a, 1973b), Vonsonhaler and Bass (1972), and others and the economic data presented by Ball and Jamison (1973), Jamison et al. (1974), and others that in many situations a favorable costs/benefits argument can be made for CAI. Presumably, there are many situations in which an equally favorable argument can be made for CMI.

It should be emphasized that empirical support for the automated prescriptions of CMI is either meager or absent. Ideally, CMI would prescribe an optimal mix of available instructional media for each student that would be appropriate for his interests and abilities and for the positions and schooling available. Determining optimal mixtures of individually prescribed instructional media is an empirical problem that the current state-of-the-art has not solved.

Finally, many applications of CMI are evolving toward, or are using, on-line, computerized testing. The effects of computerized administration of standardized off-line tests on reliability, validity, and item statistics are currently little understood and require systematic investigation before the promise of this aspect of CMI will be realized.

Use of Models

The great promise of CAI seems to lie in the individualization of instruction and in the continuous monitoring of student progress (e.g., Suppes, 1972). The former implies a need for adequate models of the learner, and the latter implies a need for adequate models of the subject matter. In effect, these two models are interdependent, and there may be little reason to distinguish between them (Fletcher, 1974). The universal, analytic learning function long sought by psychologists has never materialized, and models of the learner are currently inadequate without reference to some learning paradigm or subject matter. On the other hand, a model of subject matter may be used to represent a learner when those aspects of the subject matter that the learner has mastered are identified. The difference between these two types of models may be one of emphasis. Psychologists generally emphasize the learner, while investigators interested in artificial intelligence generally emphasize the subject matter. Issues in using models in CAI may be clustered into four areas of application: self-generating instruction, simulation, mastery, and optimization.

The most basic issues of using computers as technical aids for instructional design are addressed under the rubric of self-generating instruction. Ideally, a subject-matter specialist could engage in a computer-initiated dialogue with a model-building program that elicits the information it needs to develop a model of the subject matter in question. Presumably the model of the subject matter would not have to be complete in the technical sense, and could reflect gaps in knowledge of the subject matter. Once the model had been entered, the program could generate individualized instruction for students in accordance with a pre-specified strategy. The state-of-the-art for representing subject matter is currently more advanced than the state-of-the-art for entering the material. Brown and Collins and their collaborators have used artificial intelligence techniques to devise computer models of complex subject matter and have progressed well beyond the stage of first approximations. Despite a strong recommendation by Hickey (1974) for investigations of dialogue techniques for entering subject matter, only Hewlett-Packard's Instructional Dialogue Facility (Instructional Dialogue Facility, 1973) is a currently established application of this technique.

The use of computer-based simulation as an alternative to manipulation of specially built simulation equipment and/or hands-on laboratory experience has been receiving increasing attention. Computer-based simulations have been recommended for both instruction and evaluation, but empirical validation of these applications is lagging behind their implementation. Of particular importance is the question of how much fidelity must be maintained in a simulation to preserve the integrity of the instruction and/or evaluation being attempted. In either case, to provide an adequate computer-based simulation of a system, it is first necessary to devise an adequate computerized model of it.

The concept of mastery in training and education has been receiving considerable recent attention. As in the case of simulation, computer-based implementation of this approach to instruction is predicated upon an adequate model of the subject matter being taught. The model is required before student progress in the subject matter can be adequately determined. Even as general a theory of student progress as that presented by Suppes, Fletcher, and Zanotti (1973a) requires, as these authors emphasize, a detailed analysis of the curriculum.

Finally, optimal strategies for presenting instruction are receiving increased attention. Optimization strategies differ from maximization strategies in that the objective is not merely to maximize student achievement but to do so subject to such constraints as costs, time available, student ability, and the desired distribution of post-instruction achievement. Recent efforts to derive optimal strategies from an amalgam of mathematical models of memory, operations research, and research in CAI have produced some dramatic successes (Atkinson, 1972), but these have occurred in limited instructional situations. These techniques need to be expanded to more complex instruction applications, and this expansion will require improved models of the learner. The effectiveness of optimal strategies in CAI continues to depend heavily on models of human learning from which the strategies are derived.

Student Control

The issue of student control usually concerns how much control over CAI and/or over the computer should be given to students. One view of CAI has been of an adaptive system that would assess a student's abilities interests, and background and then present him with optimally appropriate content. Another view, held by Arthur Luehrmann (e.g., 1972) and others, is that computing is a fundamental intellectual resource which should be made available to students as well as instructors. A third view held by Merrill (e.g., 1973) and others is that a primary objective of CAI should be to help students learn to learn--with or without a computer system. These three views usually contrast under the heading of student control. Currently, this controversy appears healthy for the state-of-the-art in CAI. All three views have capable advocates who are investigating the validity of their approach with the net result of advancing the state-of-the-art. It is important to remember that these views are merely positions; all three stand in need of economic, technological, and pedagogical support. Some computer management of instruction is probably necessary as well as some student control. There is little in the state-of-the-art to argue for the exclusive application of a single approach.

Authoring and Author Languages

The issue of how CAI material should be authored, and by whom, is a current concern. For instance, a view espoused by the PLATO project is that subject matter specialists should author their own CAI material whereas a view of the TICCIT project is that CAI authoring should be accomplished by a team representing a subject matter specialist, a computer professional, and an instructional psychologist. Both views as well as intermediary positions have been advocated and applied within the military. At present, there is no authoring technique that is both simple enough and flexible enought to satisfy all users. Approaches such as the dialogue techniques for entering subject matter offer promise, but this promise is far from realization, and, given present investigations, will not include specification of instructional strategy.

Cost of Materials Preparation

The cost of preparing CAI materials remains high, but at least four instructional techniques promise major cost reductions. Frame-oriented tutorial techniques based on programmed instruction techniques are likely to remain expensive, but techniques of optimization, student control, generative CAI, and simulation should reduce costs of material preparation.

In addition to the considerable efficiencies provided by optimization techniques, piecemeal, ad hoc decisions do not have to be built into instructional materials presented under optimal strategies. At any stage of instruction, decisions for individual students are completely specified by the generalized optimal strategy chosen for the instruction rather than by pre-specified ad hoc decisions for a large number of choice points. Student control techniques, as Lahey, Hurlock, and McCann (1973) suggested, provide savings in the cost of materials preparation so long as programs using student control produce student achievement at least equal to that produced by programs using programmed branching techniques. As with optimization techniques, the cost of pre-specifying decision contingencies for numerous choice-points can be avoided. Generative CAI should provide savings by avoiding both the specification of decision contingencies and the production of course items. Further, if dialogue techniques for entering subject matter models into generative CAI can be sufficiently developed, many of the costs incurred in training subject-matter specialists about computers and in requiring them to make detailed decisions concerning the material presented can be avoided. Finally, computer-based simulation can provide a laboratory facility without expensive laboratory equipment, a source of wide experience without the investment in time usually required by such experience, and CAI without pre-specified decisions and curriculum items. In fulfilling these functions, computer-based simulation promises major reductions in materials preparation costs both for CAI and for instruction in general.

STATE-OF-THE-ART AND NAVY TRAINING NEEDS

Because of the dispersion of Navy operations, physical conditions, space limitations, and lack of uniformity of equipment, special requirements are placed on the characteristics of training systems designed to meet Navy needs. Training systems designed to increase personnel readiness aboard ship and at dockside must be: (1) capable of decreasing training costs, (2) distributed as opposed to centralized or concentrated,

(3) portable in the sense of mobility and compactness, and (4) relatively instructor free. Navy training research and development efforts must provide products that allow the redesign of existing training pipelines and the redistribution of training load with greater emphasis on enhanced capabilities for training after assignment to Fleet billets. With regard to these requirements, four aspects of CAI research and development are discussed: instruction design, instruction production, instruction delivery, and instruction evaluation. The promise of CAI lies in greater efficiency of training achieved through greater individualization. Through the use of computers, greater individualization should be possible throughout the training pipeline, and individualization is a primary concern of each of the four aspects of CAI research and development discussed.

Instruction Design

At present the major contribution of CAI to the design of instruction has been to broaden the types of instruction that must be considered by adequate techniques of instruction design. The use of computers contributes to both the problem and the solution. Much more information is needed about costs/benefits tradeoffs in CAI. Current understanding of the costs of CAI is rudimentary and superficial because most CAI efforts are, explicitly or implicitly, prototypal. Indications are that CAI used appropriately will yield substantial benefits for training efficiency, but information about how CAI achieves what it achieves is lacking. This information is essential for adequate instruction design. On the other hand, CAI contributes significantly to the solution of instruction design problems. Not only can mastery of given training objectives be assumed for all individuals being trained, but precise measures of the time it will take each individual to master given objectives can be determined. If CAI is designed to be distributed, portable, and instructor free, these assumptions and measures should be accurate throughout the training pipeline, and they should permit flexible redesign and redistribution of training. In this way CAI provides a modularity of instruction that is uniquely beneficial to the Navy.

Instruction Production

The techniques of optimization, student control, generative CAI, and simulation discussed earlier should yield improved training at a cost that is not only lower than that of current CAI materials production, but lower than many other forms of instruction materials production. Further, because production is automated and facile, it can be easily adjusted for different individuals, for different objectives within the training pipeline, and for off-line as well as on-line delivery. However, the limitations of these techniques of CAI should be emphasized. The substantial promise they offer for instruction production is generally applicable only to very well defined aspects of training. More information is needed to determine how far these techniques can be extended to the great variety of Navy training objectives.

Instruction Delivery

Compact, powerful, rugged, and inexpensive computer systems are rapidly becoming a reality. These systems can have a major impact on Navy training, in terms of both efficiency and adaptibility to the training pipeline, if research and development undertaken now provides the information necessary for their full and proper use. Much instruction of significant, proven value in schoolhouse settings can be adapted for these systems, and adaptation of this sort is of unique importance to the Navy.

The use of computers to support instruction delivery also deserves emphasis. On-line testing, test scoring, diagnostic test analysis, record keeping, optimal allocation of training resources, and personnel guidance for career planning are all functions that to some extent can be profitably automated. The benefits that accrue from the use of computers to standardize these functions and the concomitant reduction in personnel now required for their delivery are notable. However, further research and development is needed, not only to refine the computer techniques needed to support these functions, but also to determine the practicable limits of automating them. On one hand, more information is needed, for instance, about the implications for standard test statistics of on-line, computerized testing. On the other hand, more information is needed about how much test interpretation for personnel guidance should be automated. Even if it were possible to interpret test results for an individual solely by computer, it would be clearly undesirable to remove all human contact from this process. The problem is to determine an appropriate mix of computer and human contact for the interpretation of test results, and this is primarily an empirical question for research and development.

Instruction Evaluation and Modification

The precision with which training objectives can be met depends in large part on how carefully training intended for meeting these objectives can be evaluated and on how easily that training can be modified to accord with evaluative feedback. CAI offers a precision in evaluation and a facility in modification that is unique among the varieties of training media. However, the difficulties of evaluating training effectiveness are legion. Proven techniques of evaluation apply to CAI, but to what extent they can be used appropriately is unclear. Moreover, new techniques such as continuous predictive-control can now be applied to training through CAI, but, again, the promise of these techniques will be realized only through a systematic program of research and development. In any case, the facility with which training can be modified under CAI should accelerate its potential payoffs.

Final Comment

The Office of Naval Research recently organized a research program to study the all-volunteer Navy. In support of this study, Stanford Research Institute (SRI) analyzed manpower policies for the all-volunteer Navy (Battelle et al. 1973). The SRI study reached the following conclusions concerning instructional technology and savings in costs and manpower currently invested in training.

"About 20 percent of the Navy's annual investment in manpower is in training. If instructional technology were fully employed at its current state of effectiveness and cost, the technical training budget would be reduced by at least 10 percent, and the amount of manpower involved in training would be reduced by at least 20 percent. Comparable savings are expected in on-the-job training and in nontechnical training. If these savings were extended to the total annual training budget, there would be a significant impact on overall manpower costs.

Because of the large savings that are potentially available, it is strongly recommended that the Navy accelerate the systematic employment of computers and other training devices within every branch of training. Beginning on a modest scale with a few carefully selected courses, coursewriting procedures and special-purpose equipment with live training applications should be developed on shipboard and in the field. In addition, it is recommended that a formal long-term program be initiated to elevate instructional technology to a major trainig role over the next ten years. Machines should be developed that would be supportive of shipboard training and on-the-job training. Existing DoD facilities, such as the ARPA network, should be used for carrying on workshop activities among analysts in the research community, to explore the uses of shared computer facilities and shared large data bases, and to explore the use of various configurations of terminals and support equipment." (Battelle et al., p. 66-67)

These recommendations are not unique, and the suggested benefits to the Navy were known and understood before the SRI report. However, the report corroborates recommendations and benefits that seem warranted by any survey of the state-of-the-art in CAI. The success of Navy operations depends not only on maintaining readiness with current levels of manpower and equipment, but in the ability to achieve an equivalent state of readiness given the sudden increment in manpower and equipment that might arise from a national emergency. One way to accomplish this is to become as efficient as possible in training. The use of computers in training appears to hold serious promise for achieving the necessary level of efficiency.

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Technical Library, Air Force Human Resources Laboratory, Lackland Air Force Base
Technical Training Division, Air Force Human Resources Laboratory, Lowry Air Force Base
Flying Training Division, Air Force Human Resources Laboratory, Williams Air Force Base
Advanced Systems Division, Air Force Human Resources Laboratory, Wright-Patterson Air Force Base
National Research Council
National Science Foundation
Science and Technology Division, Library of Congress
Defense Documentation Center (12)